

Application No.: 10/814,992
Amendment dated: March 30, 2006
Reply to Office Action of November 30, 2005
Attorney Docket No.: 56229-153 (ANAK-248)

C. AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Currently Amended) A method for optimizing radiographic image quality by irradiating the object with x-rays from an x-ray apparatus during an initial period of an x-ray exposure, the method comprising:

A. determining a first operating voltage level kVp_0 for initial operation of the x-ray apparatus;

B. during a first sampling interval Δt_1 , in the beginning of the x-ray exposure period, operating the x-ray apparatus at said first operating voltage level kVp_0 and using one or more sensors to detect x-rays that have passed through at least a portion of the object during the interval Δt_1 ;

C. after said first sampling interval Δt_1 , processing the output signals from said sensors to determine a second operating voltage level kVp_1 ;

D. during a second sampling interval Δt_2 , operating said x-ray apparatus at said second operating voltage level kVp_1 and using said sensors to detect x-rays that have passed through at least a portion of the object during the interval Δt_2 ;

E. after said second sampling interval Δt_2 , processing the sensor output signals to determine an optimal value kVp_2 for the operating voltage level, and setting the operating voltage level of the x-ray apparatus to said optimal value kVp_2 for the remainder of the x-ray exposure period.

2. (original) A method in accordance with claim 1,
wherein said x-ray apparatus comprises an x-ray source for generating x-rays

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directed towards and through said object, and an x-ray imaging system.

3. (original) A method in accordance with claim 2, wherein said operating voltage is the accelerating voltage between an electron source and an x-ray emissive target within said x-ray source.

4. (original) A method in accordance with claim 3, further comprising: determining the optimal values of one or more additional x-ray exposure parameters of the x-ray apparatus, and setting said additional x-ray exposure parameters to said optimal values for the remainder of the x-ray exposure period.

5. (original) A method in accordance with claim 4, wherein said additional x-ray exposure parameters comprise at least one of: x-ray tube current (mA), size of focal spot, and number and type of soft x-ray filters; and wherein said x-ray tube current is the current formed by electrons emitted from said electron source, said focal spot is the area within said target upon which the electrons impinge, and said soft x-ray filters are filters for absorbing soft x-ray radiation.

6. (original) A method in accordance with claim 1, wherein each sampling interval is relatively small compared to the x-ray exposure period.

7. (original) A method in accordance with claim 1, wherein said object comprises anatomical tissue of a patient, and wherein said optimal value of said operating voltage are chosen so that the patient's exposure to x-rays is substantially minimized when the x-ray apparatus is operated at said optimal value.

8. (original) A method in accordance with claim 2, wherein said x-ray imaging system comprises one of: a) a radiographic film defining an image plane; and b) a flat panel

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detector configured to detect x-rays that have passed through said object, said flat panel detector being disposed along an image plane.

9. (original) A method in accordance with claim 8, wherein said one or more sensors are positioned between said object and said image plane.

10. (original) A method in accordance with claim 9, wherein a plurality of sensors are used to detect x-rays during said first and second sampling intervals, and wherein each of said plurality of sensors are positioned at different locations so that said sensors can detect x-rays that have traversed different portions of said object.

11. (original) A method in accordance with claim 1, wherein said object comprises anatomical tissue of a patient, and further comprising the step of measuring the thickness of said tissue before the step of determining said first and second operating voltage levels.

12. (original) A method in accordance with claim 11, wherein the step of determining said optimal value of said operating voltage level comprises:

A. calculating the differential attenuation coefficient $\Delta\mu$ of the exposed tissue at said voltage level kVp_1 , based on the output signals from said sensors, and based on the measured thickness of said tissue;

B. creating at least one $\Delta\mu$ table for at least one region of said object;

C. determining the composition of said tissue using said calculated value of $\Delta\mu$, and said at least one $\Delta\mu$ table; and

D. determining said optimal value of said operating voltage level, using said tissue composition and said $\Delta\mu$ table.

13. (original) A method in accordance with claim 12, wherein at least one $\Delta\mu$ table is

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created in step B for every centimeter of breast tissue, and wherein each of said at least one $\Delta\mu$ table defines at least two kVp values for said sampling intervals, and at least three $\Delta\mu$ values for at least three breast tissue compositions.

14. (original) A method in accordance with claim 4, wherein determining said optimal values of said additional x-ray parameters comprises:

- A. calculating the differential attenuation coefficient $\Delta\mu$ of the exposed tissue at said voltage level kVp₁, based on the output signals from said sensors, and based on the measured thickness of said tissue;
- B. creating at least one $\Delta\mu$ table for at least one region of said object;
- C. determining the composition of said tissue using said calculated value of $\Delta\mu$, and said at least one $\Delta\mu$ table; and
- D. determining said optimal values of said additional x-ray parameters using said tissue composition and said $\Delta\mu$ table.

15. (original) A method in accordance with claim 1, wherein steps B and C are repeated for a plurality of n sampling intervals $\Delta t_1^1, \dots, \Delta t_1^n$, during which the x-ray apparatus is operated at corresponding operating voltage levels kVp₁¹, ..., kVp₁ⁿ, so that said optimal operating voltage level kVp₂ is determined based on sensor output signals generated while the x-ray apparatus was operated at voltage level kVp₁ⁿ during a sampling interval Δt_1^n .

16. (currently amended) An x-ray imaging apparatus, the x-ray imaging apparatus comprising:

- an x-ray source adapted to generate x-rays directed towards and through an object;
- an x-ray imaging system configured to receive x-rays that have been emitted

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from said x-ray source and that have passed through said object, and to generate an image of said object from the received x-rays;

one or more sensors disposed between the object and said x-ray imaging system, said sensors being configured to detect x-rays from said x-ray source that have traversed said object during a first sampling period Δt_1 and a second sampling period Δt_2 , and to generate one or more output signals representative of the attenuated intensity of the detected x-rays;

a processor configured to determine a first operating voltage level kVp_0 for an initial operation of said x-ray apparatus during said first sampling period Δt_1 , said processor being further configured to calculate, after said first sampling period Δt_1 , a second operating voltage level kVp_1 by processing the output signals generated by said sensors during said first sampling period, said processor being further configured to calculate, after said second sampling period Δt_2 , an optimal operating voltage level kVp_2 by processing the output signals generated by said sensors during said second sampling period; and

a controller configured to adjust the operating voltage of said x-ray apparatus to said first and second operating voltage levels during said first and second sampling periods, respectively, said controller being further configured to adjust, after said second sampling period Δt_2 , the operating voltage of said x-ray apparatus to said optimal voltage level kVp_2 for the remainder of said x-ray exposure period.

17. (currently amended)

An x-ray apparatus in accordance with claim 16, wherein said x-ray source includes an electron source for emitting electrons, and an x-ray target for emitting x-rays from a focal spot within the target in response to incident electrons that have been accelerated from said electron source toward said target at an operating voltage of said x-ray source[.]

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18. (currently amended) An x-ray apparatus in accordance with claim [[16]]17, wherein said processor is further configured to determine the optimal values of one or more x-ray exposure parameters, and wherein said x-ray exposure parameters include at least one of operating voltage (kVp), current (mA), and size of focal spot;

wherein the operating voltage is the accelerating voltage between said electron source and said x-ray target for accelerating electrons emitted from said electron source toward said x-ray target; and

wherein the current is formed by said electrons emitted from said electron source.

19. (original) An x-ray apparatus in accordance with claim 16, wherein each of said sampling periods are relatively small compared to the total exposure time during which said object is exposed to radiation generated by said x-ray source.

20. (original) An x-ray apparatus in accordance with claim 16, wherein said x-ray imaging system comprises one of: a) a radiographic film defining an image plane; and b) a flat panel detector disposed along an image plane and configured to detect x-rays that have passed through the object.

21. (original) An x-ray apparatus in accordance with claim 16, wherein said one or more sensors comprise at least one of: an ionization chamber; a scintillator; and a solid state detector.

22. (original) An x-ray apparatus in accordance with claim 16, wherein the object comprises anatomical tissue, and wherein said processor comprises:

- A. means for calculating the thickness of the object;
- B. means for calculating the differential attenuation coefficient of the tissue at each of said first and second kVp levels based on the output signals from said

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sensors and based on the measured thickness of said tissue;

C. means for providing at least one $\Delta\mu$ table for at least one region of said object; and

D. means for computing said optimal values of said x-ray exposure parameters using said $\Delta\mu$ table.